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Structural Defects in Nd-doped Yttrium Vanadate Single Crystals

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Beamline(s): X19C

Introduction: Yttrium vanadate (YVO_4) belongs to the group of rare earth orthovanadates that crystallize with a zircon-type structure (body centered tetragonal) conforming to the space group $I4_1/amd$. YVO_4 is a very attractive material for various optical applications such as phosphor for CRT applications, polarizer and especially as laser host material when doped with trivalent Nd^{3+} ions, for diode pumped laser systems [1]. This host material offers attractive physical, mechanical and spectroscopic properties such as good mechanical strength, relatively high fracture limit, large absorption coefficient and large stimulated emission cross-section. Their lasing properties such as slope efficiency and low pumping threshold are reported to exceed those of Nd:YAG single crystals. For laser host applications, high quality, defect-free, large single crystals are required. In this study, defect structures in Czochralski grown Nd-doped YVO_4 are investigated by x-ray topography.

Methods and Materials: Czochralski crystal growth technique is employed for single crystal growth of YVO_4 , since it is advantageous from the viewpoint of growth productivity (large size crystals in relatively short period). Cross-sectional and longitudinal wafers cut from as-grown boules were characterized by synchrotron white beam x-ray topography (SWBXT) in the transmission geometry.

Results: A transmission topograph recorded from a (001) YVO_4 wafer cut transverse to the growth direction is shown in Figure 1. The wafer is composed of subgrains separated by dark and white regions caused by overlap and separation due orientation contrast. Misorientations at the subgrain boundaries are of the order of a few minutes of arc. Figure 2 shows a transmission topograph recorded from a (100) YVO_4 wafer cut parallel to the growth direction. Long columnar subgrains separated by orientation contrast are observed. Within each subgrain, striation patterns can be seen. Subgrain misorientations are of the order of several minutes of arc. This cellular structure is indicative of onset of constitutional supercooling in the melt. Optical micrographs show trails of inclusions delineating the subgrain boundaries.

Conclusions: SWBXT characterization of Czochralski grown Nd:YVO₄ crystals reveals cellular type of substructure indicative of constitutional supercooling. This is probably due to non-stoichiometry of the melt caused by incongruent loss of vanadium oxides from the melt resulting in changes in Y/V ratio and oxygen stoichiometry [2].

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References:

[1] J.R. Conner, Appl. Phys. Letters 9 (1966) 407.

[2] S. Erdei, F.W. Ainger, J. Crystal Growth, 128 (1993) 1025.

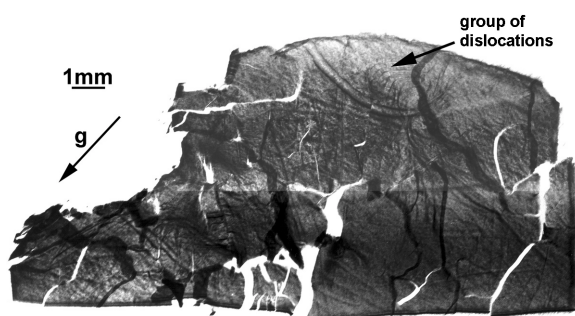


Figure 1. Transmission x-ray topograph ($g=2-20$) of a (001) YVO_4 crystal showing subgrain structure.

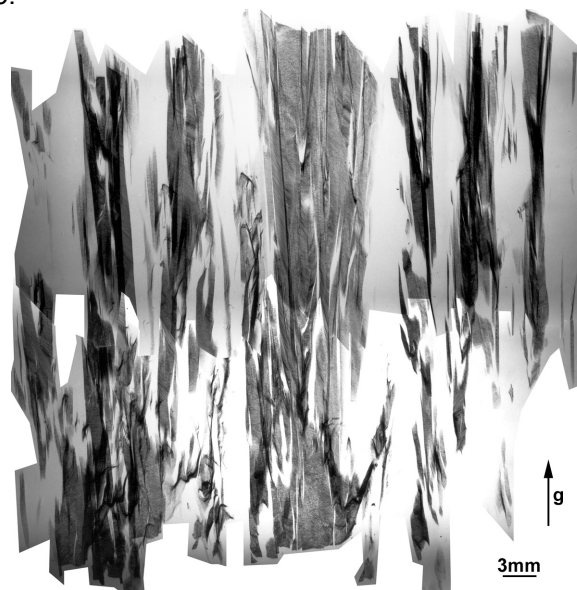


Figure 2. Transmission x-ray topograph ($g=2-20$) of a (100) YVO_4 crystal showing a columnar subgrain structure.